DECEMBER 1971

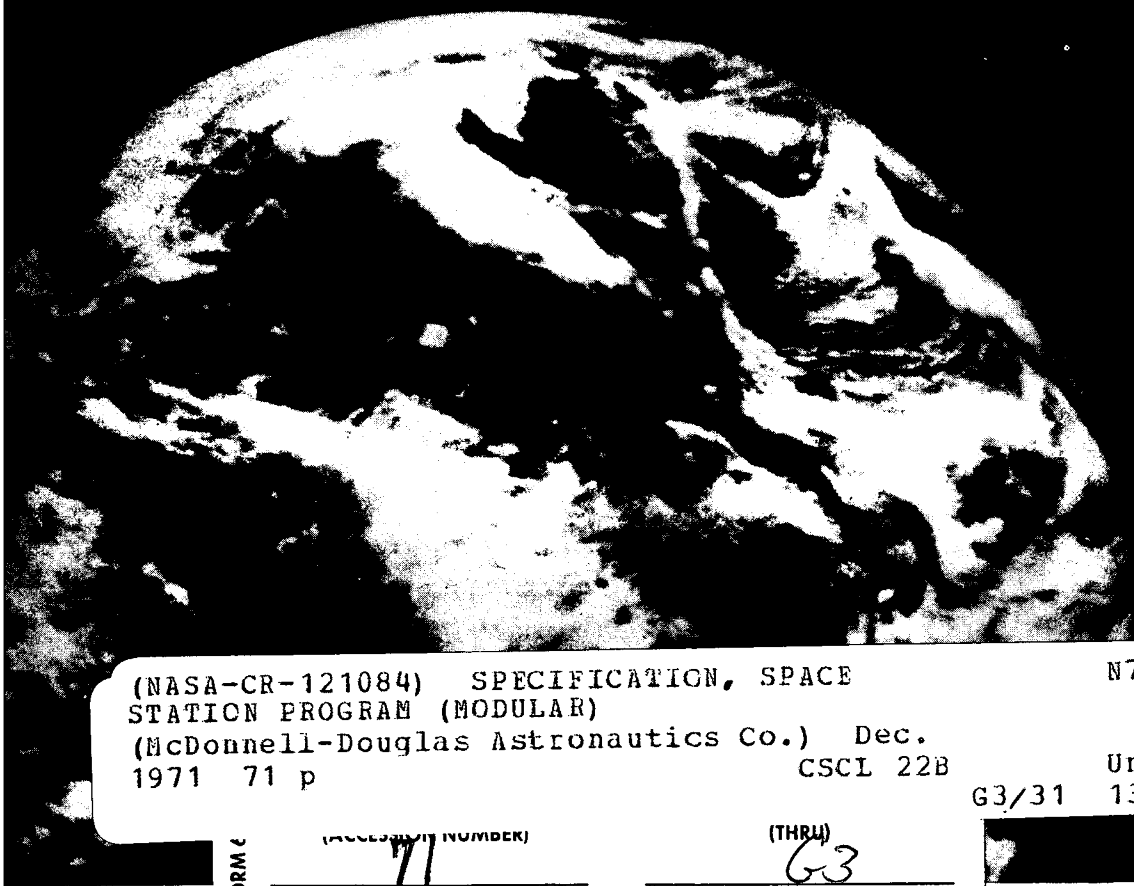
MDC G2553

SPACE STATION

MSFC-DPD-235/DR NO. CM-01

SPECIFICATION, SPACE STATION PROGRAM (MODULAR)

CONTRACT NAS8-25140



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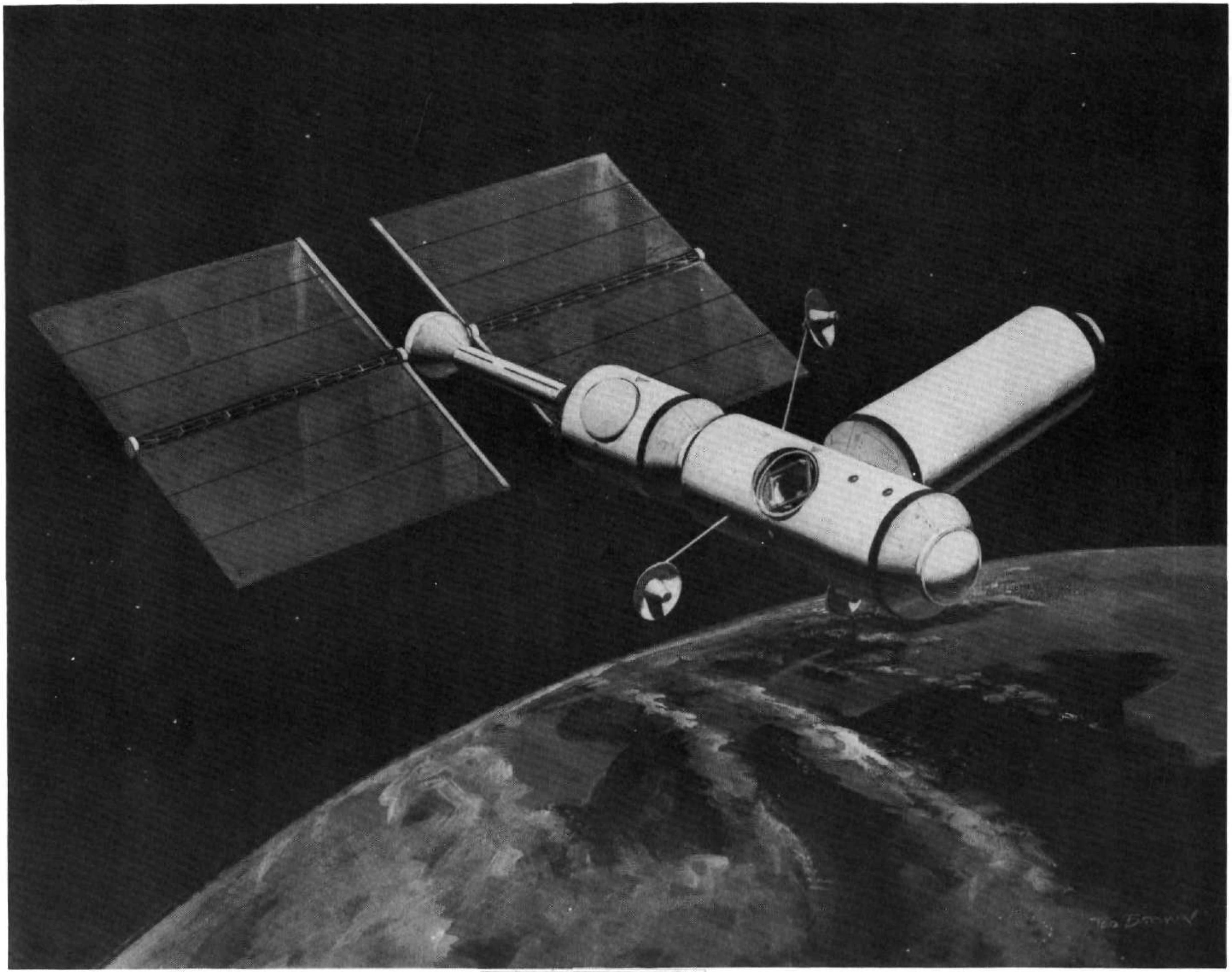

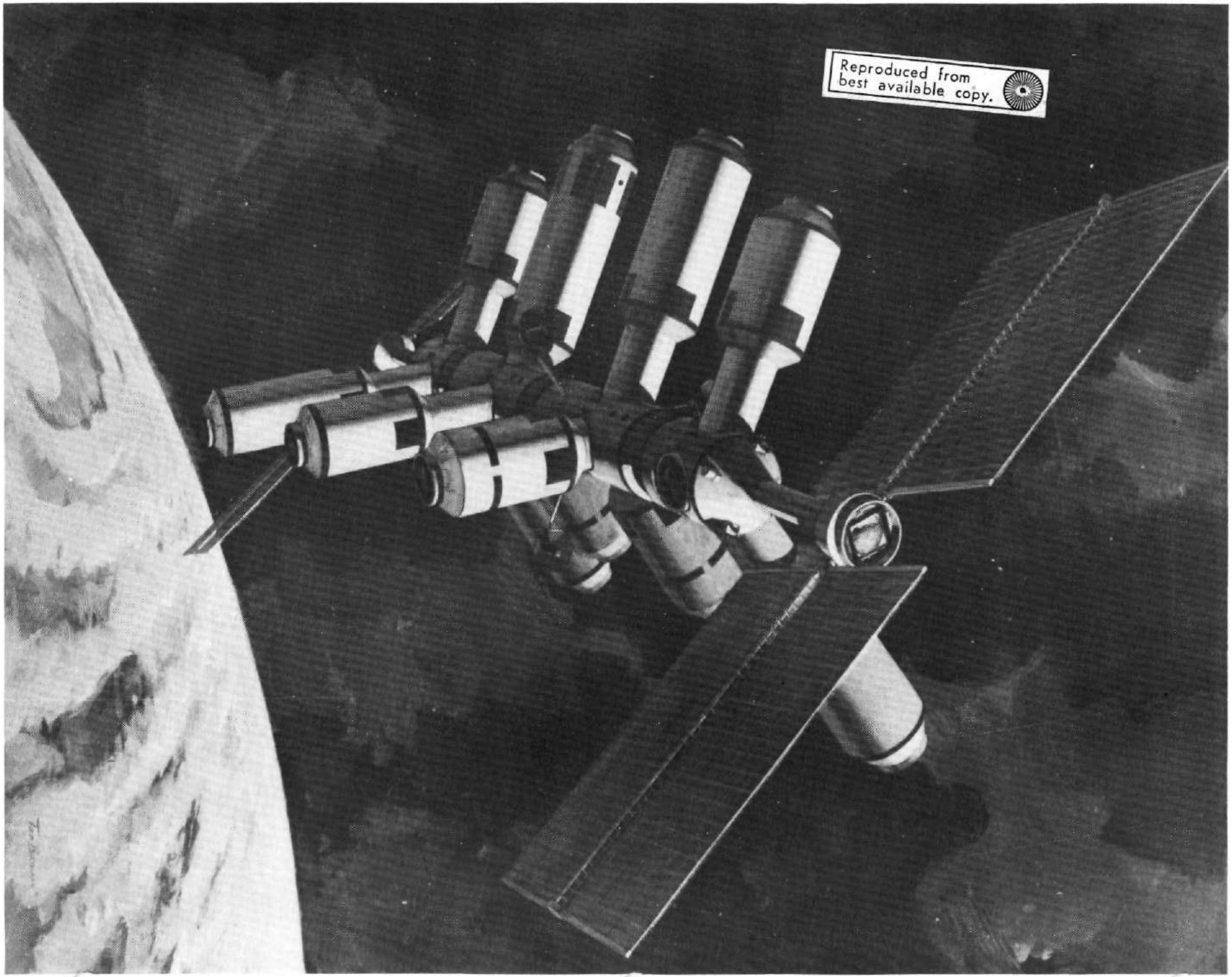

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PREFACE

The work described in this document was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the extension period has been to develop the Phase B definition of the Modular Space Station. The modular approach selected during the option period (characterized by low initial cost and incremental manning) was evaluated, requirements were defined, and program definition and preliminary design were accomplished to the depth necessary for a Phase B exit.

The initial 2-1/2-month effort of the extension period was used for analyses of the requirements associated with Modular Space Station Program options. During this time, a baseline, incrementally manned program and attendant experiment program options were derived. In addition, the features of the program that significantly affect initial development and early operating costs were identified, and their impacts on the program were assessed. This assessment, together with a recommended program, was submitted for NASA review and approval on 15 April 1971.

The second phase of the study (15 April to 3 December 1971) consisted of the program definition and preliminary design of the approved Modular Space Station configuration.

A subject reference matrix is included on page v to indicate the relationship of the study tasks to the documentation.

This report is submitted as Data Requirement CM-01.

DATA REQUIREMENTS (DR's)
MSFC-DPD-235/DR NOs.
(contract NAS8-25140)

Category	Designation	DR Number	Title
Configuration Management	CM	CM-01	Space Station Program (Modular) Specification
		CM-02	Space Station Project (Modular) Specification
		CM-03	Modular Space Station Project Part 1 CEI Specification
		CM-04	Interface and Support Requirements Document
Program Management	MA	MA-01	Space Stations Phase B Extension Study Plan
		MA-02	Performance Review Documentation
		MA-03	Letter Progress and Status Report
		MA-04	Executive Summary Report
		MA-05	Phase C/D Program Development Plan
		MA-06	Program Option Summary Report
Manning and Financial	MF	MF-01	Space Station Program (modular) Cost Estimates Document
		MF-02	Financial Management Report
Mission Operations	MP	MP-01	Space Station Program (Modular) Mission Analysis Document
		MP-02	Space Station Program (Modular) Crew Operations Document
		MP-03	Integrated Mission Management Operations Document
System Engineering and Technical Description	SE	SE-01	Modular Space Station Concept
		SE-02	Information Management System Study Results Documentation
		SE-03	Technical Summary
		SE-04	Modular Space Station Detailed Preliminary Design
		SE-06	Crew/Cargo Module Definition Document
		SE-07	Modular Space Station Mass Properties Document
		SE-08	User's Handbook
		SE-10	Supporting Research and Technology Document
		SE-11	Alternate Bay Sizes

FOLDOUT FRAME 1

FOLDOUT FRAME 2

SUBJECT REFERENCE MATRIX

LEGEND:

- CM Configuration Management
- MA Program Management
- MF Manning and Financial
- MP Mission Operations
- SE System Engineering and Technical Description

	CM				MA		MF	MP			SE								
	CM-01 Space Station Program (Modular) Specification	CM-02 Space Station Project (Modular) Specification	CM-03 Modular Space Station Project Part I CEI Spec	CM-04 Interface and Support Requirement Document	MA-05 Phase C/D Program Development Plan	MA-06 Program Option Summary Report	MF-01 Space Station Program (Modular) Cost Estimates Document	MP-01 Space Station Program (Modular) Mission Analysis Document	MP-02 Space Station Program (Modular) Crew Operations Document	MP-03 Integrated Mission Management Operations Document	SE-01 Modular Space Station Concept	SE-02 Information Management System Study Results	SE-03 Technical Summary	SE-04 Modular SS Detailed Preliminary Design	SE-06 Crew/Cargo Module Definition Document	SE-07 Modular Space Station Mass Properties Document	SE-08 User's Handbook	SE-10 Supporting Research and Technology	SE-11 Alternate Bay Sizes
2.0 Contractor Tasks																			
2.1 Develop Study Plan and Review Past Effort (MA-01)																			
2.2 Space Station Program (Modular) Mission Analysis								●											
2.3 Modular Space Station Configuration and Subsystems Definition														●					
2.4 Technical and Cost Tradeoff Studies							●												
2.4.4 Modular Space Station Option Summary											●								
2.5 Modular Space Station Detailed Preliminary Design														●					
Mass Properties																●			
2.6 Crew Operational Analysis									●										
2.7 Crew Cargo Module															●				
Mass Properties																●			
2.8 Integrated Mission Management Operations										●									
2.9 Hardware Commonality Assessment													●						
2.10 Program Support					●														
2.11 Requirements Definition																			
Space Station Program (Modular)	●																		
Space Station Project (Modular)		●																	
Modular Space Station Project—Part 1 CEI			●																
Interface and Support Requirements				●															
2.12 Plans					●														
2.13 Costs and Schedules							●												
2.14 Special Emphasis Task Information Management (IMS)												●							
Modular Space Station Mass Properties																●			
User's Handbook																	●		
Supporting Research and Technology																		●	
Technical Summary													●						
MOD 29																			●
MOD 40						●													

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CONTENTS

FIGURES

Section 1

INTRODUCTION

1.1 BACKGROUND

With the advent of the Space Shuttle in the late 1970's, providing a low cost means for inserting large payloads into various earth orbits, a long-term manned scientific laboratory in Earth orbit will become feasible. Using the shuttle for orbital buildup, logistics delivery, and return of scientific data, this laboratory will provide many advantages to the scientific community and will make available to the United States a platform for application to the solution of national problems such as ecology research, weather observation and prediction, and research in medicine and the life sciences. It will be ideally situated for Earth and space observation, and its location above the atmosphere will be of great benefit to the field of astronomy.

This orbiting laboratory can take many forms and can be configured to house a crew of up to 12 men. The initial study of the 33-foot-diameter Space Station, launched by the Saturn INT-21 and supporting a complement of 12, crewmen has been completed to a Phase B level and documented in the DRL-160 series. Recently completed studies are centered around a Modular Space Station comprised of smaller, shuttle-launched modules. These modules could ultimately be configured to provide for a crew of the same size as envisioned for the 33-foot-diameter Space Station—but buildup would be gradual, beginning with a small initial crew and progressing toward greater capability by adding modules and crewmen on a flexible schedule.

The Modular Space Station conceptual analyses are documented in the DRL-231 series. Recent Modular Space Station Phase B study results are documented in the DPD-235 series, of which this is volume.

The Space Station will provide laboratory areas which, like similar facilities on Earth, will be designed for flexible, efficient changeover as research and experimental programs proceed. Provisions will be included for such functions as data processing and evaluation, astronomy support, and test and calibration of optics. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will support operation of experiments in separate modules that are either docked to the Space Station or free-flying.

Following launch and activation, Space Station operations will be largely autonomous, and an extensive ground support complex will be unnecessary. Ground activities will ordinarily be limited to long-range planning, control of logistics, and support of the experiment program.

The Initial Space Station (ISS) will be delivered to orbit by three Space Shuttle launches and will be assembled in space. A crew in the Shuttle orbiter will accompany the modules to assemble them and check interfacing functions.

ISS resupply and crew rotation will be carried out via round-trip Shuttle flights using Logistics Modules (Log M's) for transport and on-orbit storage of cargo. Of the four Log M's required, one will remain on orbit at all times.

Experiment modules will be delivered to the Space Station by the Shuttle as required by the experiment program. On return flights, the Shuttle will transport data from the experiment program, returning crewmen, and wastes.

The ISS configuration rendering is shown in the frontispiece. The Power/Subsystems Module will be launched first, followed at 30-day intervals by the Crew/Operations Module and the General Purpose Laboratory (GPL) Module. This configuration will provide for a crew of six. Subsequently, two additional modules (duplicate Crew/Operations and Power/Subsystems Modules) will be mated to the ISS to form the Growth Space Station (GSS) (frontispiece), which will house a crew of 12 and provide a capability equivalent to the 33-foot INT-21-launched Space Station. GSS logistics support will use a Crew Cargo Module capable of transporting a crew of six.

During ISS operations, a total of five Research Applications Modules (RAM's) will be attached to the Space Station for various intervals. Three of these will be returned prior to completion of the GSS. During GSS operation, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules. The GSS has the capability for accommodating as many as ten RAM's simultaneously.

During the baseline 10-year program, the Space Station will be serviced by Shuttle-supported Logistics Module or Crew Cargo Module flights.

1.2 SCOPE OF THIS VOLUME

The Program, Project, CEI Specifications and Interface and Support Requirements Documents constitute the baseline for all Phase C/D activities and thus Space Station Program development. As shown by Figure 1-1 these specifications have resulted from the orderly development and allocation of requirements which are concise statements of performance or constraints on performance. Guidelines, established by NASA Headquarters, formed the basis for program definition and are identifiable as asterisked paragraphs within the appropriate specifications. This definition was evaluated and further expanded by a systematic development of requirements and collected in Sections 3.1 through 3.5. As the process continued, requirements that affected an interface with other programs were identified in Section 3.6; and requirements which are to be accomplished by a program element (i.e., project) were allocated to that element through Section 3.7. The methods of verifying compliance with these requirements are set forth in Section 4 of the specification.

The requirements identified in Section 3.7 of the Program Specification formed the basis for project definition as the Headquarters Guidelines did for program definition. These requirements were further evaluated and expanded resulting in the allocation of requirements to project elements (i.e., system or CEI) and their interfaces. In a like manner, Section 3.7 of the Project Specification contains those allocated requirements which define system or CEI functional performance. These in turn were evaluated and expanded in each CEI Specification, Part I. Requirements for the verification of design solutions compliance are established in Section 4 of both project and CEI Specifications.

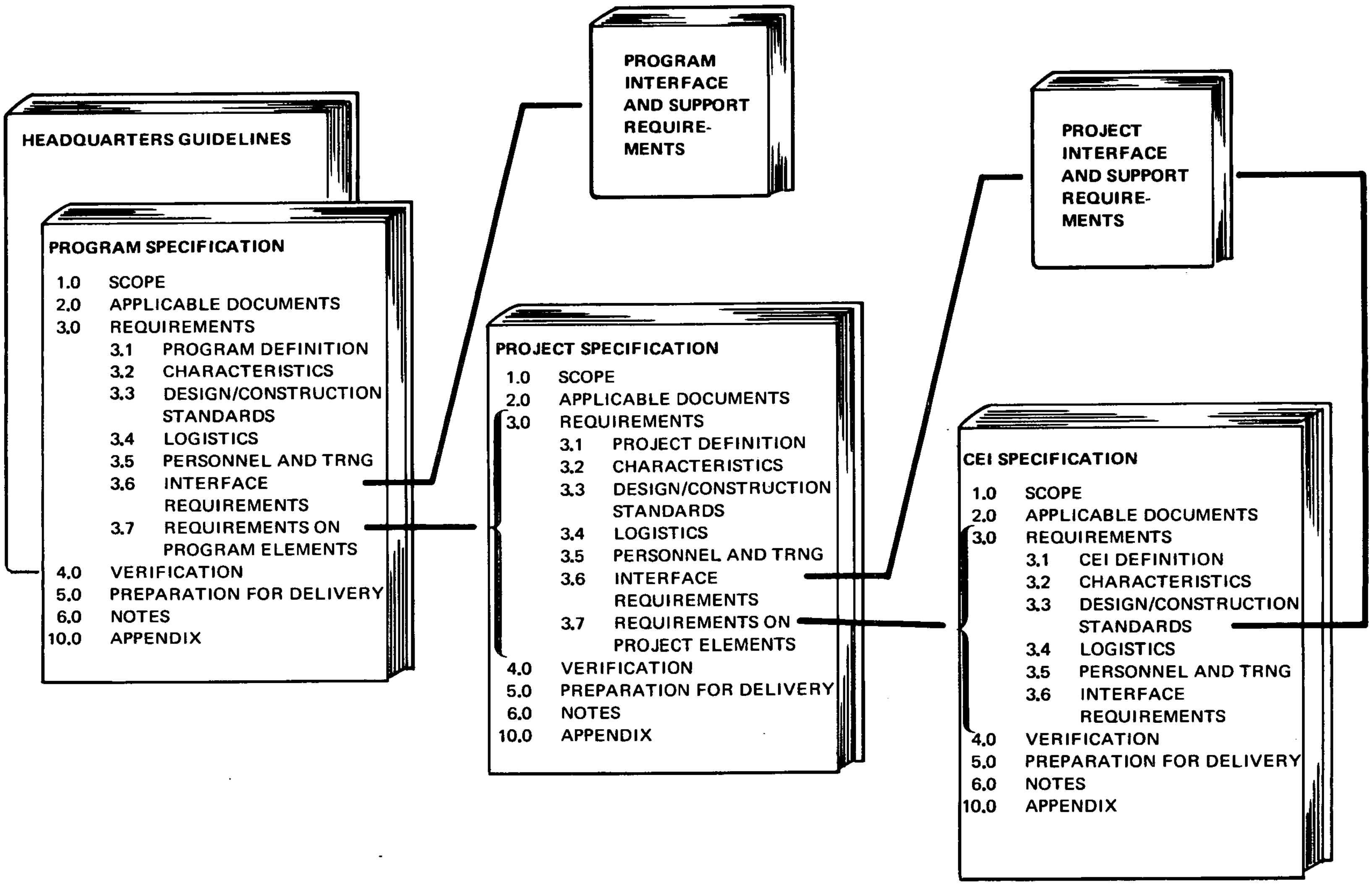

Figure 1-1. Specification Relationships

The development and structuring of requirements is vital to the interrelationship of management analyses and controls and performance measurement at various management levels and thus warrants a joint contractor-customer responsibility for the process. The Performance Requirements Document (PRD) was an evolutionary document updated by the Phase B Study contractor, but under MSFC control, which contains all identi fiable Space Station Program (Modular), project and system requirements that were defined at any point in time during the study.

This volume contains all requirements identified for the Space Station (Modular) Program. Other requirements are contained in:

- CM-02 Modular Space Station Project Specification
- CM-03 CEI Specifications
- CM-04 Interfaces and Support Requirements

Figure 1-2 illustrates the specification heirarchy and the various levels of Interface Requirements for the Space Station Program (Modular).

1.3 GLOSSARY OF TERMS

ISS	Initial Space Station
CEI	Contract End Item
GSS	Growth Space Station
WBS	Work Breakdown Structure
FM	Functional Model
FIT	Flight Integration Tool
PRR	Preliminary Requirement Review
PDR	Preliminary Design Review
RAM	Research and Application Module
CPCEI	Computer Program Contract End Item
CDR	Critical Design Review
CPC	Computer Program Component

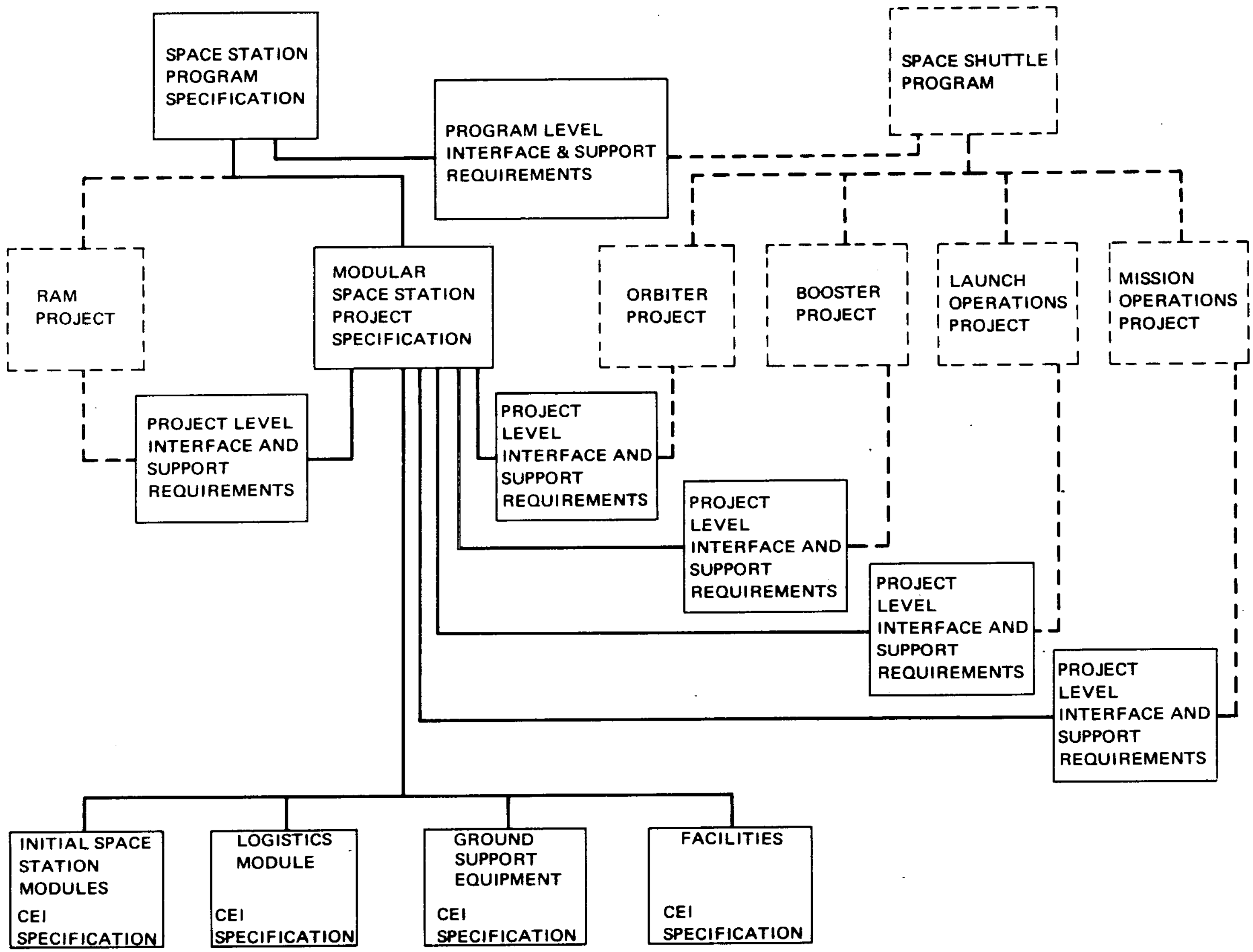

Figure 1-2. Space Station Program Specification Hierarchy

FACI	First Article Configuration Inspection
PPP	Phased Planning Project
FM	Functional Model
ICD	Interface Control Document
ER	Engineering Release
CMG	Control Moment Gyro
CH&P	Crew Habitability and Protection
GPL	General Purpose Laboratory
KSC	Kennedy Space Center
CDRL	Contract Data Requirements List
MSFN	Manned Space Flight Network
OCS	Onboard Checkout System
CIF	Central Instrumentation Facility
MSOB	Manned Spacecraft Operations Building
TDRSS	Tracking Data Relay Satellite System
DRS	Data Relay Satellite
ETR	Eastern Test Range
GBL	Government Bill of Lading
BOD	Beneficial Occupany Date
FCEI	Facility Contract End Item
LV	Launch Vehicle
GOWG	Ground Operations Working Group
FMEA	Failure Mode, Effect Analysis
I&SR	Interface and Support Requirements
CII	Configuration Identification Index
CSAR	Configuration Status Accounting Report
DRD	Data Requirement Description

IMM	Integrated Mission Management
JOA	Joint Operating Agreement
JOP	Joint Operating Procedures
TWG	Test Working Group
GSI	Government Source Inspection
MRB	Material Review Board
COQ	Certification of Quality
FMEA	Failure Mode and Effect Analysis

Specification Number PS02925
Date 10 December 1971

PROGRAM SPECIFICATION

PERFORMANCE, DESIGN AND VERIFICATION REQUIREMENTS

FOR THE

SPACE STATION (MODULAR) PROGRAM

Approved By:

W. A. BROOKSBANK, JR.
MANAGER
SPACE STATION TASK TEAM

Approved By:

T. D. SMITH
VICE PRESIDENT – PROGRAM MANAGER
SPACE STATION

PROGRAM SPECIFICATION
OUTLINE

Page

1. SCOPE

This specification defines the performance, design and verification requirements for the Modular Space Station Program as defined by the Program Development Plan. All elements and contract end items of the Modular Space Station Program shall conform to these requirements. All requirements shall be fully reflected in subsidiary specification.

2. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced, and other detailed contents of this specification, the detailed requirements herein shall be considered superseding.

SPECIFICATION	Text Reference
Federal	
MSFC-SPEC-101B, Flammability, Odor, and Outgassing Requirements and Test Procedures for Materials in Environments Which Support Combustion, March 15, 1971 (Including Amendment 1)	3.3.2.2.1
MSFC-SPEC-250, Protective Finishes for Space Vehicle Structures, February 1964	3.3.9
MSFC-SPEC-106B, With Amendment 1 and Drawing 50M02442 and 10M33107.	3.3.9
STANDARDS	
Federal	
Military	
MIL-E-6051D, Electromagnetic Compatibility Requirements, System, 7 Sept 1967, and Amendment 1 dated 5 July 1968	3.3.5
MIL-STD-143B, Standards and Specifications, Order of Precedence for the Selection of, 12 November 1969	3.3.1

STANDARDS (Continued)	Text Reference
Military (Continued)	
MIL-STD-721B, Standards and Specifications, Order of Precedence for the Selection of, 12 November 1969	3.3.1
MIL-STD-721B, Definition of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety, 25 August 1966	3.3.12
MIL-STD-810B, Environmental Test Method	
MIL-STD-1472A, Human Engineering Design Criteria for Military Systems, 15 May 1970	3.3.15
OTHER PUBLICATIONS	
Manuals	
MM8040, 12, Standard Contractor Configuration Management Requirements MSFC Programs, July 28, 1971	3.3.13, 3.1.4.3, 3.1.5
NHB 5300.4 (1A), Reliability Program Provisions	4.1.2.1
NHB 5300.4 (1B), Quality Program Provisions	4.1.2.1
Regulations	
U.S. Atomic Energy Commission Title 10 Code of Federal Regulations	3.3.7
Handbooks	
MIL-HDBK-5, Metallic Materials and Elements for Aerospace Vehicle Structures	3.3.6
MIL-HDBK-17, Plastics for Flight Vehicles, Part II Transparent Glazing Materials, 14 August 1961	3.3.6

OTHER PUBLICATIONS (Continued)	Text Reference
Handbooks (Continued)	
MIL-HDBK-23, Structural Sandwich Composites, 30 December 1968	3.3.6
NHB 7150.1, Reference Earth Orbital Research and Applications Investigations, January 15, 1971 (Blue Book)	3.7.1.1.3
TMX-53865, Natural Space Environmental Criteria for 1975-1985 for NASA Space Stations, Second Edition Dated August 1970	3.2.7.1
TMX-53872, Terrestrial Environment (Climatic) Criteria Guidelines for Use in Space Vehicle Development, September 8, 1969	3.2.7.1
TMX-53957, Space Environmental Criteria Guidelines for Use in Space Vehicle Development, August 26, 1970	3.2.7.1
SE-008-001-1 Project Apollo Coordinate Systems Standard, June 1965	3.3.11.1
Directives	
OMSF Program Directives M-Q 1700.120	3.2.6.1.1

3. REQUIREMENTS

3.1 Program Definition

The Space Station Program (Modular) shall include both the Modular Space Station and Research and Applications Module (RAM) projects.

3.1.1 General Description

The Space Station Program (Modular) will achieve major advances in the nation's space endeavors by providing a centralized facility in Earth orbit for the following purposes: (1) conduct and support of scientific and technological experiments, (2) application of the results of these experiments for the benefit of mankind, and (3) further development of space exploration capability.

* 3.1.1.1 The Space Station Program (Modular) includes the design, development and operation of a semi-permanent cluster of modules each of which can be transported to and from orbit internal to the Space Shuttle. The Modular Space Station will be capable of growth from an Initial Space Station (ISS) which minimizes development costs, to a Growth Space Station (GSS) equivalent in capability to the zero "g" 12-man, 33-foot diameter configurations defined as of August 1970.

* 3.1.1.2 Total cost of the program is a primary consideration. Primary emphasis is on minimum cost to the IOC.

* 3.1.1.3 "Commonality" is a primary consideration throughout the study. As a goal, common module structures, systems and subsystems and assemblies for Space Station modules, crew cargo modules, and Research and Applications Modules should be developed.

3.1.1.4 The Space Shuttle Program shall provide transportation for Space Station Program modules to and from low-earth orbit.

3.1.2 Missions

3.1.2.1 Beneficial space applications programs, scientific investigations, and technological and engineering experiments shall be conducted in the following areas: Earth observations, astronomy, space physics, life sciences, technology, materials science and manufacturing, communications and navigation.

3.1.2.2 The Space Station Program shall operate in orbits of 28.5- to 55-degree inclinations and altitudes between 200 and 300 nmi.

3.1.3 Operational Concepts

* 3.1.3.1 Prelaunch and launch operations will be developed so as to require minimum access to the module while in the orbiter cargo bay.

* 3.1.3.2 Shuttle launch frequency, to support the Space Station Program, will be no greater than one every 30 days.

* 3.1.3.3 The Initial Space Station shall have the capacity for independent operation with the full crew for a period of 120 days. This capacity can be included in a cargo module.

* 3.1.3.4 The Space Station will rely on the Shuttle for emergency removal of the crew with 48 hours of alert notification.

* 3.1.3.5 At least 30 days' consumables, including subsystems and experiments, will be available beyond the scheduled resupply mission.

* 3.1.3.6 Management of long range overall mission planning for the Station will be performed on the ground.

3.1.3.7 Management of short term mission planning will be performed by the on orbit Modular Space Station Crew.

3.1.3.8 All modules on orbit shall be capable of being placed into a standby, unmanned mode and be reactivated after a period of up to one year. This capability shall be provided even when any one module has been returned to the ground for major repair. Resupply flights, if required, are permissible.

3.1.3.9 Prelaunch checkout of module systems and equipment shall be performed by ground operating crew. On-orbit checkout of the module systems and equipment will be performed by the Space Station crew.

3.1.3.10 As a goal, all in-orbit modules shall have the capability of being replaced during buildup and operations with a minimum risk to crew and hardware.

* 3.1.3.11 The capability shall be provided for monitoring the Space Station in an unmanned condition to confirm the existence of a habitable environment and the functional capabilities of critical life sustaining subsystems.

3.1.3.12 There is no requirement that the Initial Space Station configuration accommodate an artificial gravity.

* 3.1.3.13 The development approach will provide the basis for reducing the number and cost of test articles and major tests and will provide for utilization of the Shuttle for on-orbit testing, as required.

* 3.1.3.14 The Initial Space Station must provide communications with the ground and other cooperating spacecraft, but not necessarily simultaneously. Interruptions in data communications with the ground network for as long as five hours will be acceptable for the Initial Space Station.

* 3.1.3.15 Nearly continuous duplex voice communications with the ground must be provided beginning with the initial manned flight. A synchronous satellite communications system will be available and provide wideband data as well as voice bandwidth communications. (A description of this system will be furnished by NASA.) Reception of wideband data, as required, should be divided between ground network stations and the synchronous satellite communications system. This division will be determined by cost considerations (see 3.1.1.2) and experiment requirements.

3.1.3.16 A synchronous satellite communication system will be available to support the first MSS launch. The system will operate in VHF (136 MHz) and Ku (15 GHz) bands.

3.1.3.17 The Space Station Program shall be planned to provide modular payloads for operation in the 1980s.

3.1.3.18 The Space Station Program shall not be required to provide payloads for both the up and down legs of any single Shuttle cycle.

3.1.4 Organizational Management Relationships

* 3.1.4.1 Space Shuttle Guidelines and Constraints, Level I, will apply to the Modular Space Station unless superseded by the Modular Station Guidelines and Constraints, Level I.

3.1.4.2 Work Breakdown Structure Organization

The Work Breakdown Structure (WBS) indicated in Figure 3-1 identifies all levels and their subdivisions in the Space Station Program (Modular). It designates appropriate levels where specifications shall be developed through systems engineering processes. It shall be expanded to designate deliverable end items, subsystems, assemblies, and components which are part of the detailed design, manufacturing, assembly, configuration, schedules, and cost. In conjunction with appropriate top-level schematics and function analyses, the WBS shall define operational functions and mission support functions.

3.1.4.3 Technical Requirements Structure

The Technical Requirements Structure (Figure 3-2) is prepared as a corollary to the WBS and identifies all levels of specifications. These specifications shall be tiered from a program specification through project (prime element) specifications, end items and software specifications (Parts I and II) in each program area. Subtier specifications associated with vendor procurement, fabrication, materials, and processes shall be consistent with upper-level specifications and responsive to the formats and requirements of MM 8040.12. Appropriate levels will be clearly identified. Major interfaces shall be indicated and documented in applicable project and

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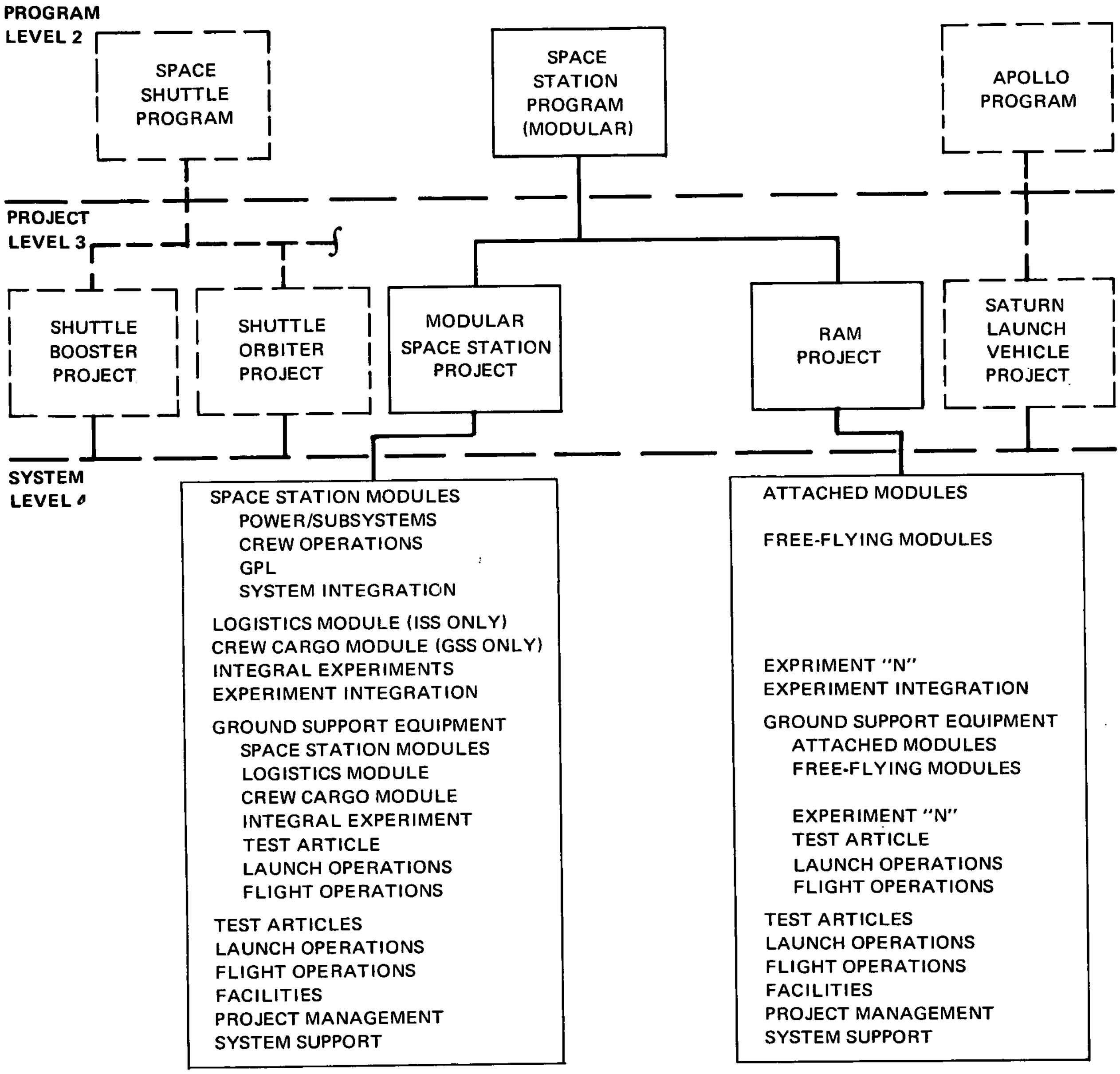

Figure 3-1. Work Breakdown Structure for Space Station Program (Modular)

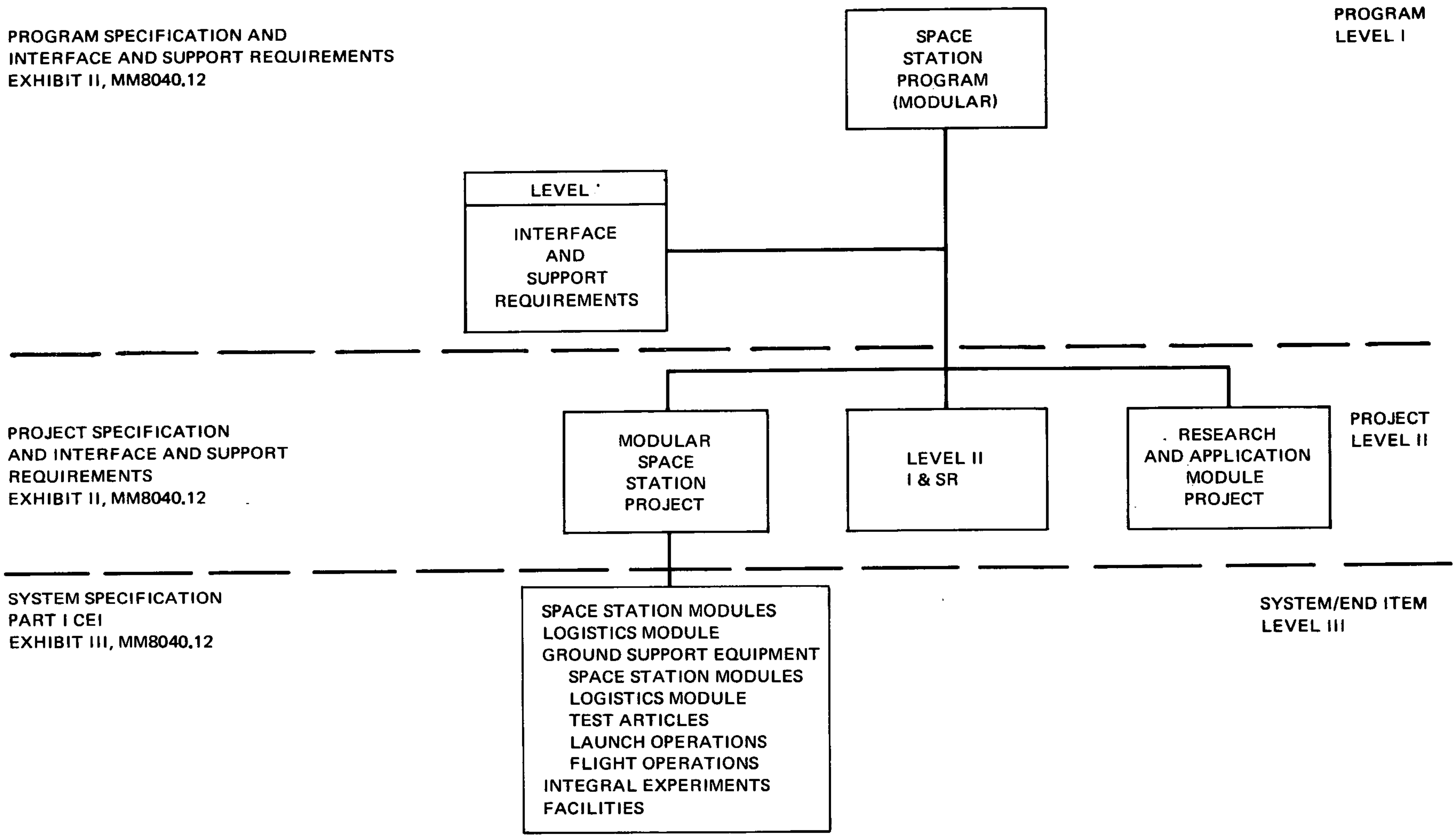

Figure 3-2. Space Station Program (Modular) Technical Requirements Structure

Contract End Item (CEI) specifications and interface control documentation shall be prepared where so indicated.

Figure 3-2 indicates the preliminary specifications and support and interface requirements documents prepared during the definition phase study. The Space Station Program and project specifications are prepared in accordance with MM 8040. 12, Exhibit III, Appendix I CEI and system specifications are prepared in accordance with MM 8040. 12, Exhibit III, Appendix II.

3. 1. 4. 4 Software Specifications

Performance requirements which must be developed for software shall be identified at any appropriate level of specification and detailed in Computer Program Contract End-Item specifications (CPCEI) as defined in MM 8040. 12, Exhibit II, Appendix VI. Appropriate interfaces with hardware and other software shall be identified and verification processes shall be designated for the validation of software and its associated interface functions.

3. 1. 5 Systems Engineering Requirements

3. 1. 5. 1 The Space Station Program (Modular) shall be structured in order to inter-relate the technical requirements structure, Work Breakdown Structure (WBS) and management structure so that they are consistent in regard to leveling and the assignment of authority/responsibilities.

3. 1. 5.2 Systems engineering methods shall define the relationships among the various levels of technical requirements, management, cost control and associated schedules.

3. 1. 5.3 Performance requirements shall be assigned, derived and allocated so that traceability and visibility is maintained from program through project to end-item specifications.

3. 1. 5.4 All applicable performance requirements shall be verified and the verification techniques for such requirements shall be established in Section 4 of appropriate specifications.

3.1.5.5 Specification practice and format shall be in accordance with MSFC MM 8040.12 configuration control documentation unless otherwise directed or approved by the contracting agency.

3.1.5.6 Interface and support requirements shall be developed for each level of specification and allocated to permit management control and performance allocations to succeedingly lower levels of development.

3.1.5.7 Systems engineering methods shall provide the necessary planning and implementation processes which expand specifications into appropriate technical and management areas for program development.

3.1.5.8 Systems engineering methods shall be used to define, schedule and control requirements/design reviews and provide techniques for the assessment of design/test results with specified performance at all levels.

3.1.5.9 Systems engineering processes shall be utilized in the expansion and definition of operational concepts.

3.1.5.10 Management responsibilities will be defined and interrelated by level, function and organizational identity.

3.1.6 Government Furnished Property List

None identified.

3.1.7 Critical Components

None identified.

3.2 Characteristics

3.2.1 Performance

The Space Station Program shall allow for the introduction of new experiment apparatus, decoupling between experiment development and vehicle development, and incorporation of new subsystems with technological advances.

3.2.1.1 Provision shall be made for the return and recovery or suitable passivation and disposal of all expended Space Station hardware and waste products. Solid wastes shall not be dumped to space.

3.2.1.2 The capability for inertial and reference (Earth/lunar/solar) attitude hold duration and attitude rate for all elements of the Space Station Program shall be (TBD).

3.2.1.3 All docking ports shall be configured to permit docking with any other docking port, inherently or with use of a standard adapter kit.

3.2.1.4 The Space Station shall provide for a hard Shuttle docking capability via the payload module.

* 3.2.1.5 A minimum of two separate pressurized habitable compartments with independent life support capability and provisions and other essential services will be provided at each manned stage of cluster buildup and operation.

3.2.1.6 Where cost effectiveness can be demonstrated, maximum use will be made of standard laboratory equipment. Modification and space qualification testing of such equipment will be minimized.

3.2.1.7 No attitude constraints will be imposed by communications.

3.2.2 Physical

* 3.2.2.1 The "design to" weight of Shuttle-transported modules shall not exceed 20,000 pounds.

* 3.2.2.2 The maximum external dimensions of the modules shall be 14 feet in diameter and 58 feet in length. Mechanisms that are external but attached to the module, such as handling rings, attachments for deployment, docking mechanisms, storage fittings, thrusters, etc., shall be contained, at launch, within an envelope of 15 feet diameter and 60 feet length.

* 3.2.2.3 The docking port and hatches shall provide a nominal diameter of 5 feet and provide utility interfaces within the pressurized volume.

3.2.2.4 Space Station Module weight delivered to orbit shall include all program items contained in the 15 x 60 foot bay envelope, plus those payload items located in the Orbiter crew or passenger compartments (i.e., passengers, removable provisions and display/control console, etc.).

3.2.3 Reliability

3.2.3.1 Space Station Program (Modular) reliability shall be constrained to the precise assessment of operating life for limited durations. Operating life shall be assessed based upon a worst-case 90-day resupply cycle. Equipment with a high probability of failure or wear-out of less than 90 days will be supported by a maintainability approach which permits on-orbit repair and replacement with onboard spares inventory. Equipment which can be conservatively projected into operating life expectancies of greater than 90 days shall be supported with a maintainability and logistics criteria which shall permit resupply on a 90-day cycle and scheduled replacement within that cycle. The Space Station Program probability of mission success (total support of any single experiment) shall be (TBD) for any 90-day period, assuming on-orbit maintenance. Ten-year mission success (total support of all experiment programs) probabilities shall be factored products of the 90-day probabilities.

3.2.3.2 Useful life of items, assemblies, subassemblies, components, and/or parts shall be established by testing, engineering analysis, or previous use.

3.2.3.3 Established useful life shall be utilized in development of redundance and maintenance requirements and inventory policy.

3.2.3.4 Reliability assessments, analysis, and tradeoffs shall be utilized as one source in identifying new technology requirements.

3.2.4 Maintainability

* 3.2.4.1 Maintenance and repair will be accomplished on the ground when cost effective. Module return will be traded against on-orbit repair and replacement.

3.2.4.2 Sufficient spares shall be available to support TBD days operation and maintenance of life essential and mission survival functions without dependence on any single resupply flight during the TBD day interval.

3.2.5 Operational Availability

* 3.2.5.1 The Space Station Program Phase C go-ahead is assumed to be in FY 76. The total program length is not specified. However, the program will provide an identifiable plateau in the Initial Space Station configuration, will reach full Growth Space Station capability five to six years after launch of the first Initial Space Station module, and will continue Growth Space Station operations for five years.

3.2.6 Safety

3.2.6.1 General

3.2.6.1.1 Space Station Program (Modular) safety policies shall be in accordance with OMSF Program Directive M-DMQ 1700.120.

* 3.2.6.1.2 Safety is a mandatory consideration through the total program. As a goal, no single malfunction or credible combination of malfunctions and/or accidents shall result in serious injury to personnel or to crew abandonment of the Space Station.

3.2.6.1.3 All safety hazards shall be identified in order of criticality. Catastrophic or critical hazards shall be eliminated or reduced to controllable or acceptable risk levels.

3.2.6.1.4 Modules containing hazardous materials or devices shall have protective provisions, while being transported by the Orbiter, as to not compromise the safety of the Orbiter.

3.2.6.2 Development

* 3.2.6.2.1 The atmosphere constituents, including harmful airborne trace contaminants and odors will be monitored and controlled in each pressurized habitable volume.

* 3.2.6.2.2 The Space Station shall be divided into at least two pressurized habitable volumes so that any damaged module can be isolated as required. Accessible modules will be equipped and provisioned so that the crew can safely continue a degraded mission and take corrective action to either repair or replace the damaged module.

* 3.2.6.2.3 Atmospheric stores and subsystem capacity sufficient for one repressurization shall be maintained on the Space Station during manned operations to independently supply each pressurized habitable volume.

* 3.2.6.2.4 Critical onboard subsystems will be designed to minimize risk or loss of modules, injury to the crew or damage to the Shuttle and other interfacing vehicles.

*R 3.2.6.2.5 For those hazards that may result in time critical emergencies, provisions shall be made for automatic switching to a safe mode and to display caution and warning to personnel.

3.2.6.3 Crew

* 3.2.6.3.1 Two or more suited crewmen will participate in any pressure suit activity and rescue provisions will be provided.

* 3.2.6.3.2 Personnel escape routes shall be provided in all hazardous situations. A design goal shall be to provide alternate escape routes that do not terminate into a common module area.

* 3.2.6.3.3 The allowable radiation limits for the crew are listed below:

Organ	Limit Dose (rem)				
	1-Yr Avg Daily	30 Day	Quarterly*	Yearly	Career
Skin (0.1mm)	0.6	75	105	225	1200
Eye (3.0mm)	0.3	37	52	112	600
Marrow (5.0cm)	0.2	25	35	75	400

*May be allowed for two consecutive quarters with 6 months restriction from further exposure to maintain yearly limit.

3.2.6.4 Orbital Operations

* 3.2.6.4.1 Access to an EVA and IVA airlock suit station(s) shall be provided for all credible emergency conditions. Airlock chamber(s) shall be provided to permit crew access for EVA/IVA operations.

3.2.6.5 Emergency/Abort

3.2.6.5.1 Two independent cues are required for a mission abort decision. The source of these cues can be from the Space Station displays, downlink telemetry, or physiological reactions of the flight crew. Redundant sensors are required if two independent cues of a failure cannot be obtained.

3.2.7 Environment

3.2.7.1 Natural

Space Station Program (Modular) flight hardware shall withstand the environments specified in the following documents for a 10-year period with repair, replacement and maintenance as required.

a. NASA Technical Memorandum Report No. TMX-53865, Second Edition dated August 1970.

b. NASA Technical Memorandum Report No. TMX-53872.

c. NASA Technical Memorandum Report No. TMX-53957, Second Edition dated August 1970.

Space Station Program (Modular) launch support hardware which may be exposed to natural environments shall withstand without adverse effects the environments specified in NASA TMX-53872.

3.2.7.2 Induced

Environmental effects may be induced by Space Station Program elements upon themselves or another element, or by an element of another program. Induced environmental limits affecting other program elements shall be specified in Section 3.6 of the appropriate level specification.

3.2.7.2.1 Induced environmental loads shall be established for all phases of operations.

3.2.7.2.2 Cumulative effects of induced environments shall not exceed specified limits.

3.2.7.2.3 The design of each program element shall be based on withstanding the induced environment levels originating from other program elements and shall not exceed specified levels.

3.2.7.2.4 Space Station Program payloads shall be capable of withstanding as a minimum the load factors established as required in the subtier specifications, and the Interface and Support Requirements Documents.

3.2.7.2.5 Space Station Program modules shall be capable of withstanding the Shuttle Orbiter cargo bay temperature and ambient pressure ranges specified in the sub-tier specifications and the Interface and Support Requirements Documents.

3.2.8 Transportability/Transportation

3.2.8.1 Transportation and handling criteria and policy shall be based on structural characteristics and induced environment criteria utilized in design of operational hardware. Transportation loads shall not exceed operational design loads.

3.2.8.2 The maximum air transportation weight and volume shall not exceed existing air transport capabilities.

3.2.9 Storage

None identified.

3.3 Design and Construction Standards

3.3.1 Selection of Specifications and Standards

All materials, parts, and processes shall be defined by standards and specifications. Standards and specifications shall be selected from Government, industry, and contractor specifications and standards in accordance with MIL-STD-143B. Rationale for the selection of contractor specifications and standards over existing higher order or precedence standards and specifications shall be compiled and maintained for historical record. This rationale shall include an identification of each higher order or precedence specification or standard examined and state why each was unacceptable.

For purposes of this order or precedence, commercial materials, parts and processes shall be considered equivalent to contractor standards.

3.3.2 General

3.3.2.1 Design and construction standards for hardware obtained from the Saturn, Apollo, Gemini, or other Space programs shall be in accordance with existing specifications for those items and in accordance with the standards below, as appropriate. New Space Station Program hardware shall be designed and constructed in accordance with standards in the following sections.

3.3.2.2 Dangerous Materials and Components

3.3.2.2.1 Space Station Program hardware shall be designed in accordance with MSFC-SPEC-101B, with Amendment 1.

*R 3.3.2.2.2 All materials selected for use in habitability areas will be nontoxic, nonflammable, and nonexplosive to the maximum extent practical.

3.3.3 Aeronautical

None identified

3.3.4 Civil

Federal, state, and local codes shall be observed as necessary for construction, fabrication, transportation, communications, and safety.

3.3.5 Electrical

The Space Station Program as a total system shall comply with the requirements of MIL-E-6051D.

3.3.6 Mechanical

The structural and mechanical systems shall have sufficient strength and rigidity to sustain yield load without failure, without deformation which would prevent any portion of the vehicle from performing its intended function and without deleterious permanent set. The simultaneous application of accompanying environmental effects (temperature, pressure, slosh and vibration) shall be applied to determine the critical loading conditions. These systems shall have sufficient strength and rigidity to withstand the ultimate design load without failure and without deformation which would result in premature failure of any safety critical function. Simultaneous application of accompanying environmental effects shall be considered in determining the critical loads. Extremes of the environmental effects with appropriate loads shall be considered. Analysis shall be performed to assess the effects of dynamic magnification, shock factors and surge phenomena as applicable. Design data and materials properties shall be obtained from MIL HDBK 5, MIL HDBK 17, MIL HDBK 23 or alternatively from other sources which meet the approval of the procuring agency.

3.3.7 Nuclear

Design practice associated with the containment, handling, and safety of nuclear materials and devices shall comply and be subject to AEC policies and practices defined by Title 10 Code of Federal Regulations.

3.3.8 Moisture and Fungus Resistance

Materials which are not nutrients for fungus shall be used whenever possible. The use of materials which are nutrients for fungus shall not be prohibited in hermetically sealed assemblies and other accepted and qualified uses, such as paper capacitors and treated transformers. If it is necessary to use nutrient materials in other than such qualified applications, these nutrient materials shall be treated by a method which will render the resulting exposed surface fungus resistant. The treated surface must satisfactorily pass the fungus tests in MIL-STD-810B.

3.3.9 Corrosion of Metal Parts

Parts including spares shall be protected against corrosion and stress corrosion. Protective methods and materials for cleaning, surface treatment, and application of finishes and protective coating shall be accomplished in accordance with MSFC-SPEC-250, and MSFC-SPEC-106B with Amendment 1 and drawings 50M02442 and 10M33107.

3.3.10 Contamination Control

3.3.10.1 No effluents (wastes, propulsion, ventings, material outgassing, etc.) shall deleteriously affect the Space Station, attached modules, adjacent spacecraft, or any of their experiments or measurements. The effects of effluents on the elements shall be minimized by design, including selection of material, outlet locations, direction of flow, sequencing, filtering, or sealing. The resultant effects shall be consistent with the requirements for crew EVA, experiments, optical devices, logistics and ancillary vehicle docking, structures, thermal control, and effective engine performance.

3.3.11 Coordinate Systems

3.3.11.1 The coordinate axes and reference planes shall be in accordance with NASA SE-008-001-1.

3.3.12 Interchangeability and Replaceability

Mechanical and electrical interchangeability shall exist between identical replaceable parts, assemblies and subassemblies, regardless of manufacturer or supplier. All parts having the same part number, regardless of source, shall be functionally and dimensionally interchangeable as defined in MIL-STD-721.

3.3.13 Identification and Marking

Equipment, assemblies, and parts shall be marked for identification in accordance with MM 8040.12, Exhibit IV.

3.3.14 Workmanship

Space Station Program hardware, including all parts and accessories shall be constructed and finished in a thoroughly workmanshiplike manner. Particular attention shall be paid to neatness and thoroughness of soldering, wiring, impregnation of coils, markings of parts and assemblies, plating, painting, riveting, machine-screw assemblage, welding and brazing, and freedom of parts from burrs and sharp edges.

3.3.15 Human Performance/Human Engineering

The criteria specified in MIL-STD-1472A shall be met as a minimum in the design of program hardware.

3.4 Logistics

3.4.1 Space Station Program elements shall rely on the Space Shuttle for transport to and from low earth orbit.

3.4.2 A depot concept shall be utilized to provide spares and crew support supplies.

3.4.3 In orbit, the Space Station shall provide logistics management and the capability to replenish depleted consumables for all attached and free flying modules.

3.4.4 The Space Station Program shall make maximum use of the logistics facilities of the Mission Management Complex.

3.5 Personnel and Training

3.5.1 Space Station projects shall provide training for all flight personnel to their respective payloads, including station keeping and experimentation.

3.6 Interface Requirements

3.6.1 Interprogram

3.6.1.1 Space Station Program (Modular)/Space Shuttle Program Reference PS02926—"Program Level Interface and Support Requirements, Space Station Program (Modular)/Space Shuttle Program."

3.6.2 Intraprogram

3.6.2.1 Modular Space Station Project/RAM Project, Reference Appendix A—"Intraprogram Interface Requirements, Modular Space Station Project/RAM Project."

3.6.3 Not Applicable

3.7 Requirements for Program Elements

3.7.1 Modular Space Station

3.7.1.1 General

* 3.7.1.1.1 The Initial Space Station shall be operational when fully manned (three to six crewmen), and fully configured including a general purpose laboratory capability in addition to at least two Research and Application Modules.

* 3.7.1.1.2 The Growth Space Station shall be sized to accommodate 12 crewmen and shall have integral laboratory facilities, research support provisions (power, information management, docking ports, etc.) and habitability provisions equivalent to those provided by the 33-foot diameter designs in the Phase B study reported in August 1970.

* 3.7.1.1.3 The Initial Space Station shall be capable of supporting selected, partial, modified, or combined FPE's from the Blue Book, NHB 7150.1 Blue Book experiments and RAM's are to be scheduled in accordance with Station capability. Modified FPE's will require the approval of NASA.

* 3.7.1.1.4 The Growth Space Station will have the capability to accommodate all Blue Book FPE's, but not simultaneously.

3.7.1.2 Missions

* 3.7.1.2.1 The Space Station will be capable of use in an orbit at 55° inclination at an altitude between 240 and 270 nautical miles.

3.7.1.3 Operational Concepts

3.7.1.3.1 Space Station Project shall design and develop modules for the support of RAM experiments, and crews, and provide the necessary equipment and services to maintain, operate and manage a ten year orbital mission.

3.7.1.3.2 Space Station Project/ISS shall be operational during CY 1981.

3.7.1.3.3 The Growth Space Station shall reach full operational capability in CY 1985.

3.7.1.4 Characteristics

* 3.7.1.4.1 The Initial Space Station will utilize subsystems and components that minimize development costs prior to IOC.

* 3.7.1.4.2 The Initial Space Station will be sized to accommodate at least six crewmen. Provisions for double occupancy will be provided in case they are required during relief crew overlap periods.

* 3.7.1.4.3 Provisions and habitable facilities shall be adequate to sustain the entire crew for a minimum of 96 hours during an emergency situation requiring Shuttle rescue.

* 3.7.1.4.4 The Space Station will provide private crew quarters for the nominal crew.

* 3.7.1.4.5 The Space Station shall have windows arranged to allow both earth and celestial viewing.

* 3.7.1.4.6 The Space Station will be capable of accommodating a mixed male-female crew.

* 3.7.1.4.7 Onboard systems will be provided for checkout, monitoring, warning, and fault isolation to a level consistent with safety and with the in-orbit maintenance and repair approach selected. Emergency control and repair of failures or damage will also be provided. As a goal the overall Station operations will not be substantially degraded by selected repair modes.

* 3.7.1.4.8 The EC/LS system will provide a shirt sleeve environment within habitable areas for crew activities during the buildup, activation periods and module replacement period.

* 3.7.1.4.9 The Space Station structure and subsystems will be designed for an oxygen/nitrogen mixture at a normal operating pressure of 14.7 psia.

* 3.7.1.4.10 Carbon dioxide partial pressures will be maintained below 3.0 mm Hg in all habitable areas.

3.7.1.4.11 A CO_2 partial pressure of 7.6 mm Hg shall be allowed for 7 days during an emergency.

* 3.7.1.4.12 ISS electrical power will be provided by solar arrays. Minimum average load electrical power requirement is 15 KW at the load bus, averaged over a 24-hour period.

* 3.7.1.4.13 As a goal, no orientation restrictions will be imposed by subsystems, i.e., electrical power, thermal control, communications.

* 3.7.1.4.14 The environmental control and life support subsystem shall be designed with a closed wash water loop. Closure of other functional loops will be based on the appropriate trade data.

3.7.2 Research and Applicable Modules

3.7.2.1 General

*R 3.7.2.1.1 The Research and Applications Modules (RAM) project includes the design, development and operation of Research and Applications Modules accommodating selected or partial functional program elements (FPE) which can be transported to and from orbit internal to the Space Shuttle. The RAM is a project element of the Space Station Program.

*R 3.7.2.1.2 The January 15, 1971 Blue Book Reference Earth Orbital Research and Applications Investigations NHB7150.1 will be the basis of defining the payloads (experiment/equipment) for the RAM's. Modification to the FPE's as defined in the Blue Book will require NASA concurrence. Payloads may consist of combined, partial or complete FPE's.

3.7.2.1.3 A RAM support module which supports RAM's in the Shuttle tended mode and is capable of providing the necessary habitability for personnel and services (e.g., stabilization and control, power, comm, data processing, checkout) will be designed as an element of the RAM project. The support module will be operated attached to the Shuttle.

*R 3.7.2.1.4 RAM's development will be based on subsystems and components that minimize initial program costs.

3.7.2.2 Missions

3.7.2.2.1 The RAM's shall be designed to operate in two missions:

3.7.2.2.1.1 In the Shuttle-supported mode, the RAM's will have the capability to operate attached to the Shuttle Orbiter for periods up to 30 days performing compatible FPE experiment or detached in a free flying mode with the Shuttle Orbiter providing for resupply in a tender mode.

3.7.2.2.1.2 In the Space Station-supported mode the RAM's operate either attached to the Space Station or free flying with the Space Station supporting their operation. The Shuttle is the logistics system.

3.7.2.3 Operational Concepts

*R 3.7.2.3.1 The free-flying RAM's must be able to communicate with the Shuttle, RSM, or Space Station, and the Ground Network and Synchronous Satellite, Communications System, but not necessarily simultaneously. Interruptions in data communications with ground networks for as long as five hours will be acceptable.

*R 3.7.2.3.2 Free-flying modules will be designed to accept and respond to guidance and navigation from the RSM, Space Station, or the ground. The Shuttle or the Space Station shall control rendezvous and docking of RAM's.

*R 3.7.2.3.3 During operations the attached RAM's will utilize Space Station or RAM support module and Shuttle subsystems for electrical power, guidance and navigation, stabilization control, atmospheric composition control/life support, communications, etc.

*R 3.7.2.3.4 A synchronous satellite communications system will be available and provide wideband data as well as voice bandwidth communications. (A description of this system will be furnished by NASA.) Reception of wideband data, as required, should be divided between ground network stations and the synchronous satellite communications system. This division will be determined by cost considerations and experiment requirements.

*R 3.7.2.3.5 In addition to ground checkout, onboard subsystems will be capable of on-orbit checkout controlled from the Space Station, the support module in the Shuttle or from the ground.

*R 3.7.2.3.6 RAM's will be unmanned in the free-flying mode.

3.7.2.4 <u>Characteristics</u>

3.7.2.4.1 RAM's will be designed to accept complete FPE's but must be capable of initial operations with partial FPE's and subsequent growth to the complete status.

*R 3.7.2.4.2 The RAM's shall be designed such that it can be isolated at the attachment plane from any attached pressurized compartment in case the RAM is damaged or rendered untenable.

*R 3.7.2.4.3 The module structure and subsystems will be designed to accommodate a normal operating pressure range of 10 to 14.7 psia in the habitable areas. Repressurization of the RAM will be provided by the Space Station or RAM support module.

3.7.2.4.4 Attached RAM's will transfer electronic data via hardline to the Space Station.

*R 3.7.2.4.5 The design approaches will accommodate module subsystems and experiment related equipment, which may require servicing and maintenance, in areas that are easily accessible.

*R 3.7.2.4.6 As a goal, free-flying RAM's will be designed to facilitate their retrieval and recovery by the Shuttle in case of failure of critical onboard systems.

4. VERIFICATION

4.1 General

Verification of performance requirements shall be mandatory at all specification levels and shall be established by systems engineering analyses, for all levels of test, operations and mission performance evaluation. This section defines Space Station Program (Modular) verification policy and requirements. The project specification shall expand verification policy, designate a verification approach for all prime elements, and establish specific requirements applicable to the elements. The CEI specification shall include the detailed verification requirements for each deliverable item. The purpose of this section is to insure that the design and performance requirements identified in Section 3 are attained and are verified in the most economical and effective manner. This section defines responsibility for verification of requirements, the agencies who will perform the verification, verification methods to be used including the criteria to be used in selecting these methods, and the agencies, facilities and equipment which will support the verification effort.

4.1.1 Responsibility for Verification

This paragraph establishes organizational responsibilities at the program level for performing and supporting verification. NASA Headquarters Space Station Program Office, by means of this specification, establishes overall verification policy for the Space Station program. The field centers are responsible for verification of design characteristics, functional performance and operability requirements.

4.1.1.1 Verification Management

4.1.1.1.1 Program

The Program by means of this specification shall establish over-all verification policy and requirements. This policy shall specify program verification requirements which, in addition to verifying the Level I performance, design and interface requirements, establish the management principles and technical guidelines to structure a cost-effective verification program. The Program is responsible for verification of all Space Station program requirements from design concept through system operation. The verification of program elements shall be in accordance with Paragraph 4.2, Phased Verification Requirements and Table 4-1, Verification Cross Reference Index.

4.1.1.1.2 Project

Each Project shall define verification requirements in a project specification which are consistent with policies established by the Program and which specify technical requirements for Modular Space Station operations. The Project shall establish test plan requirements to ensure compatible operations and adequate design verification. The following verification phases which involve two or more Space Station Projects are assigned to TBD lead centers for establishment of detail verification requirements and implementation of the verification program:

a. Integrated Systems Verification
b. Prelaunch Verification
c. Flight/Mission Verification
d. Post Flight Verification

The Modular Space Station Project and the Research and Application (RAM) Project shall verify all project level requirements within their respective projects. The verification of project elements shall be in accordance with

Section 4 of the Modular Space Station Project Specification and Section 4 of the RAM Project Specification.

4.1.1.1.3 End Item Manager

Each End Item Manager shall approve the verification requirements of Section 4, Part I CEI Specifications. Each CEI Manager shall be responsible for maintaining this specification so that Section 4 reflects the current verification philosophy for Section 3 design/performance requirements, and shall ensure that verification plans and methods are consistent with specification requirements of all management levels. Each end item manager shall be responsible for cost, schedule and technical performance of the CEI.

4.1.1.1.4 Contractor

Each CEI contractor shall develop verification requirements for all CEI performance/design requirements, including CEI to CEI interface requirements. These verification requirements shall address all performance requirements and not merely those relating to acceptance of the CEI. He shall implement the verification program at the working level through test plans which shall be prepared with the guidance of the Verification Plan Requirements. The contractor must exhibit traceability through these plans to satisfy CEI and program/project specification requirements.

4.1.1.2 Phase Responsibilities

The types of verification applicable during each phased development are indicated in Figure 4-1.

4.1.1.2.1 Development

Development shall be conducted to verify the feasibility of the design approach and provide the contractor with confidence in the ability of his CEI to pass qualification. Development tests shall be conducted primarily to obtain empirical data to support the design and development process. As such, the extent of this verification shall be left to the contractor for determination, definition and supportive documentation. Within the definition, however, the relationship of these activities to the development process shall be described. In those few special cases, where by agreement of the contractor and NASA CEI Manager, development tests data verifies performance/design requirements, the responsibilities for performance and support specified for qualification shall pertain.

4.1.1.2.2 Qualification

The extent and scope of qualification verification shall be identified and controlled by NASA CEI Manager/contractor action to assure the flight-type or ground support-type equipment will meet the performance and design requirements. Qualification shall be performed and documented by the contractor and/or his subcontractor using standard, accredited supportive practices. Each project/CEI office shall specify within the project/CEI specification its review and approval requirements. These requirements shall include as a minimum the review and approval of individual qualification results.

4.1.1.2.3 Acceptance

Acceptance verification shall be performed and supported by the CEI contractor with complete buy-off documentation such as logs, test history, test results, records of inspection, discrepancies, deficiencies, review board activities and corrective action. These activities shall be performed by the CEI contractor under NASA surveillance to verify that the end item conforms to CEI performance requirements and is equivalent to previously qualified end items.

4.1.1.2.4 Integrated Systems

Integrated Systems verification performance and support responsibilities related to the verification of integrated systems (CEI) performance shall be defined at the project level and bilaterally agreed upon by the interfacing project/CEI offices. These agreements shall be stated as requirements and recorded in the appropriate Interface and Support Requirements document (I&SR). Intra-project requirements shall be addressed within the appropriate Project Specification. These verifications may be conducted by NASA and/or a contractor.

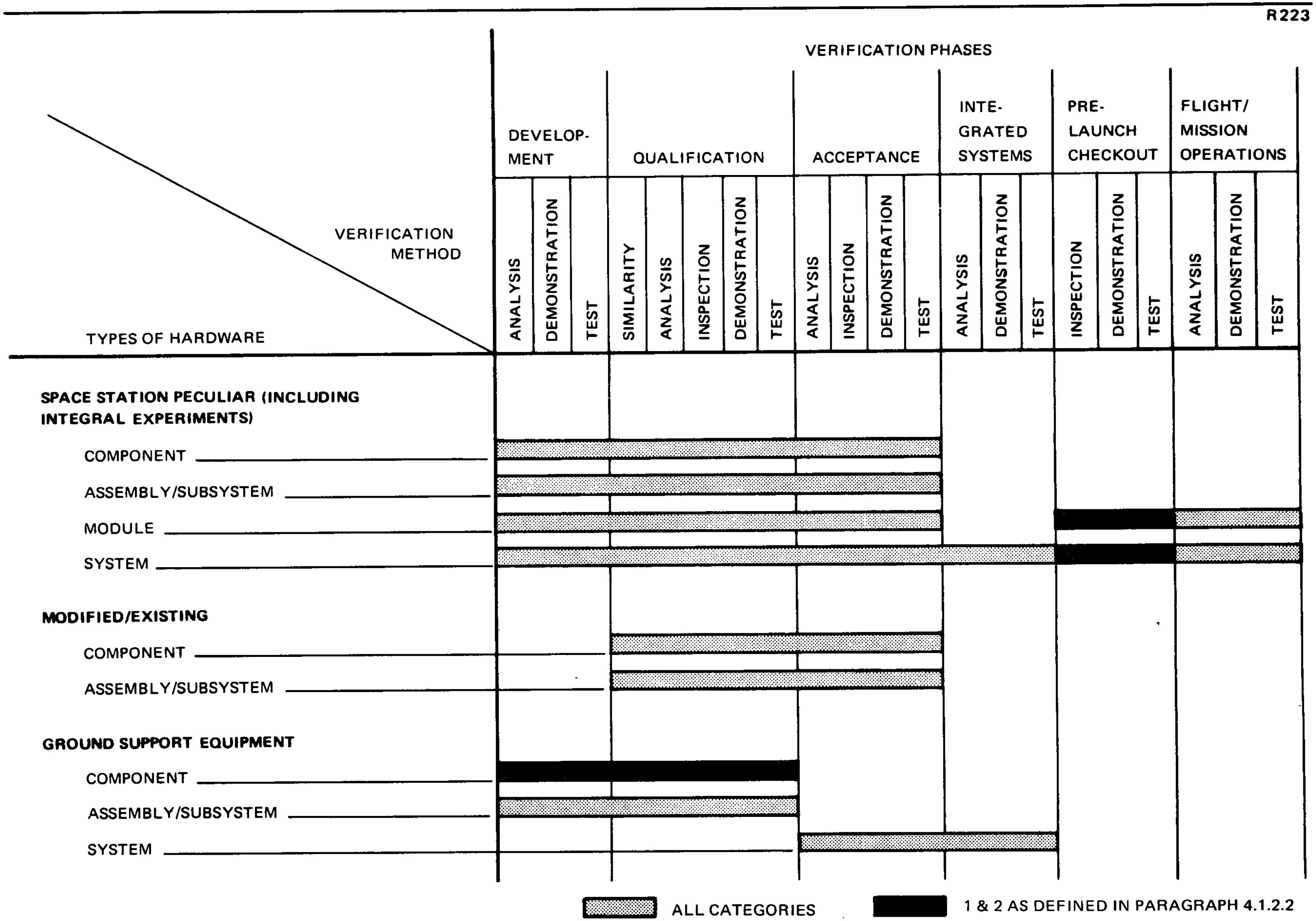

Figure 4-1. Verification Method Requirements

4.1.1.2.5 Prelaunch Checkout

Each contractor shall be responsible for verifying that his CEI is ready for launch and launch support. These requirements shall be specified in the appropriate I&SR and related Project Specifications.

4.1.1.2.6 Flight/Mission Operation

4.1.1.2.6.1 Space Station Mission Management in conjunction with the Space Shuttle Mission Operations Project shall be responsible for flight operations performance. Requirements for this verification will be addressed at the project level.

4.1.1.2.6.2 Space Station Program orbital buildup and operations verification shall be the joint responsibility of NASA and the Initial Space Station module system contractor. Requirements for the ISS phase buildup and operational verification shall be specified in the Modular Space Station Project Specification.

4.1.1.2.7 Post Flight

All modules, equipment, or experiments returned to Earth from the Space Station either because of failure or planned return shall have a post flight evaluation conducted to determine cause of failure or to verify that it performed in accordance with specification requirements.

4.1.2 Verification Method Selection

Each requirement of Section 3 shall be verified by either assessment or test. Section 4.3 contains a matrix which identifies the method selected for verifying Section 3 requirements and also references the applicable verification requirements of Section 4.2. This section specifies the criteria for verification method selection.

4.1.2.1 Selection Criteria

Using a systems engineering approach, verification requirements shall be defined based on criticality categories, design margins and technical parameters and shall be compatible with the OMSF Program

Directive M-DMQ 1700-1, Reliability Program Provisions [NHB 5300.4 (1A)], Quality Program Provisions [NHB 5300.4 (1B)], and Configuration Management (MM8040.12).

4.1.2.1.1 Assessment

Space Station Program (Modular) design and performance requirements that can be verified by assessment shall be in accordance with one of the following methods:

a. Similarity may be used if (1) it can be shown that the article is similar or identical in design and manufacturing process to another article that has been previously qualified to similar criteria, and (2) analysis of dissimilarities either in design, manufacturing processes or verification criteria substantiates that the article will perform its intended function within the specified envelope. Similarity shall pertain to characteristics such as material, configuration, and functional element or assembly, and may be applied selectively for applicable environments.

b. Analytical techniques may be used in lieu of or to supplement testing as appropriate to verify specification requirements such as maintainability useful life, reliability and those requirements which cannot be verified by other methods, e.g., zero-g testing. The selected techniques may include systems engineering analysis, statics, qualitative analysis, and computer simulation.

c. Inspection shall be used wherever adequate to verify such requirements as features, drawing compliance, workmanship, and physical condition of the end item.

d. Demonstration shall be used when actual conduct operation can verify attainment of requirements such as service and access, maintainability, transportability, human engineering features, or performance. This method shall be used in lieu of test, when possible, to verify crew restraints and habitability performance requirements.

4.1.2.1.2 Test

Each test program shall be defined so that testing other than development testing is performed in direct response to a Section 4 requirement and when an acceptable level of confidence cannot be established by any of the above assessment methods or if testing can be shown to be the most cost effective method. Efforts shall be made to obtain the maximum amount of verification data from the tests conducted, in order to minimize the number of tests required. Analysis shall be conducted to determine the difference between test data and anticipated operational data, e.g., environmental difference, structural strain.

4.1.2.2 Criticality Categories

Criticality categories are established for flight and ground support hardware to provide guidelines for determining the test emphasis consistent with attaining the objectives of mission success and crew safety. This categorization is predicated on the possibility of equipment failures which may be human or equipment induced. The criticality categories are as follows:

Category	
1	Loss of life of crew members(s) (ground or flight).
1S	Applies to safety and hazard monitoring systems. When required to function because of failure in the related primary operations system(s), potential effect of failure is loss of life of crew member(s).
2A	Immediate mission flight termination or unscheduled termination at the next planned earth landing area, including loss of primary mission objectives.
2B	Launch scrub.
3	Launch delay, including loss of secondary mission objectives.
4	None of the above.

4.1.3 Relationship to Management Reviews

NASA will confirm that the requirements for verification specified in Section 4.2 and the methods and phases identified in the Verification Cross Reference Index, Section 4.3, are appropriate and provide NASA the assurance of meeting the specified requirements in the most cost effective manner.

4.1.3.1 Preliminary Requirements Review (PRR)

4.1.3.1.1 PRR shall be conducted by the Program Office.

4.1.3.1.2 The Program (Project) Requirements Baseline shall be established at PRR by reviewing and approving the Program and/or Project Specifications. Project level verification requirements shall be substantiated at this time and plans for any project level tests reviewed.

4.1.3.1.3 Preliminary project level design approach and verification concepts shall be reviewed at PRR to ensure that necessary actions are taken to establish a meaningful Design Requirements Baseline and there is general compatibility with program guidelines. PRR shall serve to review program level verification requirements and more specifically development tests required to select and substantiate design approaches.

4.1.3.2 Preliminary Design Review (PDR)

4.1.3.2.1 The PDR shall be conducted by the Project Office.

4.1.3.2.2 The purpose of the PDR is to verify by formal review the suitability of the baseline design approach early in the design phase. The verification plan presented at the PDR shall include the methodology for verification of applicable Development and Qualification requirements specified in Section 4.2 of this document. Development verification shall begin after the establishment of a baseline design at the PDR. Qualification verification on long lead items shall begin as soon as possible after the PDR. The Part I CEI specification listing the performance and design requirements and verification methods for the end item shall be approved at the PDR.

4.1.3.3 Critical Design Review (CDR)

4.1.3.3.1 The CDR shall be conducted by the Project Office.

4.1.3.3.2 The CDR is a formal technical verification review of the end item hardware near the end of the design phase. Verification requirements presented at the CDR shall include the updated Part I CEI Specification, the preliminary Part II CEI Specification and a formal test plan which includes the methodology for verification of the applicable portion of Section 4.2 of this program specification. The expanded test plan presented at this design review (ref. 4.1.3.2) shall include verification requirements for Qualification, Integrated System, Prelaunch Checkout, Flight/Mission Operations, and Post Flight Verification. Development and Qualification analysis and test results that have taken place since the PDR shall be presented at the CDR.

4.1.3.4 Configuration Inspection (CI)

4.1.3.4.1 The CI shall be conducted by the Project Office.

4.1.3.4.2 The Configuration Inspection is a formal technical review to determine if the end item hardware has been built and verified in accordance with the Part II CEI Specification which is presented at the CI for approval. The CI establishes that verification was performed and that the as-built hardware did in fact comply with the requirement of the Part I CEI Specification. The verification documentation and hardware presented at CI shall verify the applicable portion of Section 4.2 of this program specification.

4.1.3.5 Post-CI Reviews

The status of verification shall be reviewed at each major milestone and documented prior to initiation of the next activity. Management reviews shall be utilized to perform these reviews. As a minimum these reviews shall occur at completion of integrated systems verification, prelaunch checkout, orbital buildup and at the time of a movement of the flight article.

Specific requirements for these reviews shall be stated herein by completion of PRR.

4.1.4 Test Equipment Failures

4.1.4.1 Test Failures

When a failure occurs, failure analyses shall be accomplished before the hardware is removed, altered, or the test continued. This does not preclude conducting additional tests aimed at resolving the failure. The analysis should disclose the cause of the failure, e.g., operator error, test equipment malfunction, procedural error, malfunction of external input to the system, or failure of the hardware being tested. The analysis should further determine if degradation or damage has occurred elsewhere in the system as a result of the failure. Tests may continue on systems not affected by the failure. If the failure analysis has not disclosed the cause of failure, the malfunctioning hardware shall be removed from mission use.

4.1.4.1.1 Tests shall be conducted strictly according to documented procedures.

4.1.4.1.2 Failure of hardware during the course of component qualification tests disqualifies the test item. The failure shall be analyzed to determine if the results of previous tests are invalidated by the failure or by any corrective action taken. Then testing must be reinitiated, going back to the beginning of that part of the test where failure occurred, repeating earlier tests, if required. It is particularly important during end item hardware level testing and combined testing that the cause of failure be understood and that the hardware and/or procedural changes be clearly identified in order to establish high confidence in qualification of failed item during rerun.

4.1.4.2 Test Articles

4.1.4.2.1 Test articles shall be identified so that they may be distinguished from identical articles for flight or operational use. Refurbishment of test articles for operational use shall be considered, however, test articles which are used in development and qualification tests shall not be used as flight hardware except as specifically approved by the government. Test articles not used in flight hardware shall be disposed of in accordance with approved salvage procedures.

4.1.4.3 Test Equipment

Any failure of test equipment during a test shall be cause for immediately cessation of test. Cause and impact of failure shall be determined, and corrective action identified and recorded. The test equipment shall be repaired or refurbished if economically feasible, otherwise it shall be disposed of in accordance with approved salvage procedures.

4.1.5 Verification of Unplanned Equipment Uses

Any piece of hardware or software may be used in an unplanned mode if the unplanned usage is both within the operational limits for which it was verified and such usage does not compromise the success of the mission. In emergency cases where unplanned usage will exceed verified limits, these new limits shall be verified as effectively as possible in the time available.

4.2 Phased Verification Requirements

4.2.1 Development

Development verification shall be accomplished by analysis, demonstration or test, or combinations thereof.

4.2.1.1 Sufficient development verification shall be conducted to provide confidence in the design approach.

4.2.1.2 Except as directed the extent of development verification shall be left to the CEI contractor for determination and definition.

4.2.2 Qualification

Qualification verification shall be by similarity, analysis, inspection, demonstration or test, or combinations thereof.

4.2.2.1 Flight-type and ground support type equipment shall be qualified for verification of performance and design requirements under anticipated operational environments.

4.2.2.2 Qualification tests shall be conducted on hardware identical to the flight article.

4.2.2.3 Induced environment testing shall be performed at the assembly/ subsystem level. Testing will be performed at highest possible level within this constraint.

4.2.2.4 As a goal, environmental missions profile qualification testing shall be minimized.

4.2.2.5 Hardware that has been used on previous programs shall only be qualified for those additional critical environments.

4.2.2.6 The 10-year lifetime requirement shall be verified by a combination of testing and analysis.

4.2.3 Acceptance

Acceptance verification shall be by analysis, inspection, demonstration or test, or combinations thereof.

4.2.3.1 CEI level environmental acceptance testing shall not be required.

4.2.3.2 Induced environment acceptance testing, where required, shall be accomplished as early as possible in the assembly to preclude expensive retest costs.

4.2.3.3 Physical dimension and weight inspections shall be performed by the contractor at the factory.

4.2.3.4 All inspections and analyses shall be accomplished against released engineering.

4.2.3.5 Program level acceptance shall be performed by the contractor with NASA surveillance.

4.2.4 Integrated Systems

Integrated Systems verification shall be by analysis, inspection, demonstration or test, or combinations thereof.

4.2.4.1 Interproject interfaces and program performance shall be demonstrated on the ground. These demonstrations shall be conducted in conjunction with project integrated systems verification.

4.2.4.2 Inspections shall be accomplished against released engineering.

4.2.5 Prelaunch

Prelaunch verification shall be by inspection, demonstration or test, or combinations thereof.

4.2.5.1 Prelaunch checkout shall be conducted in accordance with released procedures and Orbiter/Station agreements.

4.2.5.2 Module docking/dedocking capability and interface compatibility shall be checked out at the launch site prior to installation into the Orbiter cargo bay. This checkout shall be conducted by launch operations.

4.2.6 Flight/Mission Operations

Flight/Mission operations verification shall be by analysis, demonstration, or test or combinations thereof.

4.2.6.1 Adequate instrumentation shall be provided to assess previously performed assessment techniques and results, under operational conditions.

4.2.6.2 Flight plans shall specify verification operations and procedures.

4.2.6.3 During buildup and at the initiation of unmanned periods, the station crew shall verify the operations of critical functions. This verification shall be performed in accordance with pre-established flight plans and monitored by ground operations.

4.2.6.4 Ground operations shall conduct analyses at predetermined intervals to assess and forecast Space Station performance.

4.2.7 <u>Post Flight</u>

Post flight verification shall be accomplished by analysis, demonstration, inspection or test or any combinations thereof.

4.3 <u>Verification Cross Reference Index</u>

This section contains a one-for-one cross reference of each verification requirement for each Section 3 requirement and identifies the method by which each requirement is to be verified.

4.4 <u>Test Support Requirements</u>

4.4.1 <u>Facilities and Equipment</u>

4.4.1.1 Test facilities and equipment already in existence shall be used to the maximum extent regardless of ownership (industrial, NASA or other government agencies).

4.4.1.2 Test equipment needed to simulate inputs/outputs to subsystems shall be compatible with the onboard checkout and fault isolation system and other interfacing subsystems.

4.4.1.3 All test equipment shall be certified to ensure that no damage or degradation is introduced into the test hardware or that results will not include test equipment error.

4.4.1.4 Special high levels of atmospheric or surface cleanliness shall not be required for verification processes unless necessary to the requirement being verified.

4.4.1.5 Tests shall be conducted and test equipment/articles located for most beneficial use to the entire mission duration.

4.4.1.6 Tests involving incremental or complete performance at more than one location shall be designed to use common test equipment and procedures.

4.4.2 Articles

4.4.2.1 Test articles shall be identified in the appropriate specification and shall use the following as goals:

a. Minimize the number of test articles.
b. Maximize the use of hardware and computer programs used for other test functions.
c. Minimize the number of equivalent test articles.
d. Maximize the use of mockups, trainers and integration fixtures throughout the mission duration.

4.4.3 Software

4.4.3.1 Subsystem and integration testing will require complete or interim versions of deliverable scheduled computer programs or portions thereof. However, in the conduct of most test, additional, non-deliverable computer programs are needed to control the specimen or test environment as well as to simulate interfaces. Policies shall be established for designing and coding to ensure that these computer programs are compatible with software and consistent with the appropriate CP segment logic.

4.4.3.2 Compatible compilers and languages shall be used where feasible to ensure efficiency and simplified flow from hardware contractor development to final integration activities.

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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

A. Development
B. Qualification
C. Acceptance
D. Integrated Systems
E. Prelaunch Checkout
F. Flight/Mission Operations
G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.0	X								
3.1	X								
3.1.1	X								
3.1.1.1	X								
3.1.1.2	X								
3.1.1.3	X								
3.1.2	X								
3.1.2.1	X								
3.1.3	X								
3.1.3.1						4			4.2.5.1
3.1.3.2	X								
3.1.3.3							5		4.2.6.1, 4.2.6.2
3.1.3.4							3		4.2.6.3
3.1.3.5							3		4.2.6.3
3.1.3.6							5		4.2.6.1, 4.2.6.2
3.1.3.7							5		4.2.6.1, 4.2.6.2
3.1.3.8							3		4.2.6.3
3.1.3.9						5			4.2.5.2
3.1.3.10							5		4.2.6.1, 4.2.6.2
3.1.3.11	X								
3.1.3.12	X								
3.1.3.13							5		4.2.6.1, 4.2.6.2

REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

A. Development
B. Qualification
C. Acceptance
D. Integrated Systems
E. Prelaunch Checkout
F. Flight/Mission Operations
G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.1.3.14							5		4.2.6.1, 4.2.6.2
3.1.3.15							5		4.2.6.1, 4.2.6.2
3.1.4	X								
3.1.4.1	X								
3.1.4.2	X								
3.1.4.3	X								
3.1.5	X								
3.1.6	X								
3.1.7	X								
3.2	X								
3.2.1	X								
3.2.1.1							3		4.2.6
3.2.1.2							5		4.2.6
3.2.1.3						5			4.2.5.2
3.2.1.4						5			4.2.5.2
3.2.1.5							3		4.2.6
3.2.1.6							3		4.2.6
3.2.1.7							5		4.2.6
3.2.2	X								
3.2.2.1				4					4.2.3.3
3.2.2.2				4					4.2.3.3

REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

A. Development
B. Qualification
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Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.2.3				4					4.2.3.3
3.2.3	X								
3.2.3.1							3		4.2.6.3
3.2.3.2	X								
3.2.3.3							3		4.2.6.3
3.2.3.4	X								
3.2.4	X								
3.2.4.1							5		4.2.6.1, 4.2.6.2
3.2.4.2							5		4.2.6.1, 4.2.6.2
3.2.5	X								
3.2.5.1							5		4.2.6.1, 4.2.6.2
3.2.5.2							5		4.2.6.1, 4.2.6.2
3.2.6	X								
3.2.6.1	X								
3.2.6.1.1				4					4.2.3.4
3.2.6.1.2				4					4.2.3.4
3.2.6.1.3							3		4.2.6.3
3.2.6.1.4					4				4.2.4.2
3.2.6.2	X								
3.2.6.2.1				4					4.2.3.4
3.2.6.2.2							5		4.2.6.1, 4.2.6.2
3.2.6.2.3							3		4.2.6.3

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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

A. Development
B. Qualification
C. Acceptance
D. Integrated Systems
E. Prelaunch Checkout
F. Flight/Mission Operations
G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.6.2.4							3		4.2.6.3
3.2.6.2.5							3		4.2.6.3
3.2.6.3	X								
3.2.6.3.1							5		4.2.6.1, 4.2.6.2
3.2.6.3.2							3		4.2.6.3
3.2.6.3.3							3		4.2.6.3
3.2.6.4	X								
3.2.6.4.1							3		4.2.6.3
3.2.6.4.2							5		4.2.6.1, 4.2.6.2
3.2.6.5	X								
3.2.6.5.1							3		4.2.6.3
3.2.7	X								
3.2.7.1	X								
3.2.7.2	X								
3.2.7.2.1	X								
3.2.7.2.2							3		4.2.6.3
3.2.7.2.3	X								
3.2.8	X								
3.2.8.1	X								
3.2.8.2	X								
3.2.9	X								

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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

A. Development
B. Qualification
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D. Integrated Systems
E. Prelaunch Checkout
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G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.3	X								
3.3.1	X								
3.3.2	X								
3.3.2.1				4					4.2.3.4
3.3.2.2	X								
3.3.2.2.1				4					4.2.3.4
3.3.2.2.2				4					4.2.3.4
3.3.3	X								
3.3.4				4					4.2.3.4
3.3.5				4					4.2.3.4
3.3.6				3					4.2.3.4
3.3.7				4					4.2.3.4
3.3.8				4					4.2.3.4
3.3.9				4					4.2.3.4
3.3.10	X								
3.3.11	X								
3.3.11.1							5		4.2.6.1, 4.2.6.2
3.4	X								
3.5	X								
3.6	X								
3.6.1						5			4.2.5.1
3.6.2					5				4.2.4.1

5. PREPARATION FOR DELIVERY

5.1 Modules and components of the Modular Space Station Program shall be protected from natural environmental extremes specified in section 3.2.7. Selection of preservation and packaging methods shall be compatible with transportation, storage and handling requirements.

6. NOTES

10. APPENDIX

Appendix A - Intraprogram Interface Requirements, Modular Space Station Project/RAM Project.

SPACE STATION PROGRAM (MODULAR)
APPENDIX A
INTRAPROGRAM INTERFACE REQUIREMENTS
MODULAR SPACE STATION PROJECT/RAM PROJECT

3.0 REQUIREMENTS

This appendix contains requirements affecting the interface(s), both physical and supportive, of the Modular Space Station Program elements with one another. These requirements are specified by the program manager and as such do not necessitate bilateral agreement. Bilateral agreements between Space Station Program elements are specified within the Level II Interface and Support Requirements.

3.1 Project Definition

3.1.1 The Space Station shall provide the capability to support at least two attached RAM's in the ISS configuration. The Growth Space Station shall have the capability of supporting a maximum of six attached and three free flying RAM's.

3.2 Characteristics

3.2.1 Performance

3.2.1.1 The normal mode of command and control data transmission for the RAM modules shall be from/to the Space Station. The communication system shall be sized for zero db omni antennas on the Space Station.

3.2.1.2 The Space Station shall provide FFM with tracking data.

3.2.1.3 FFM's shall transmit only scientific data and status information to the Space Station.

3.2.1.4 All RAM life critical parameters to be monitored by the Space Station shall utilize hardline transmission.

3.2.1.5 Control and display for RAM's shall make maximum use of control and display in the Space Station.

3.2.1.6 A redundant duplex voice channel shall be provided between all docked RAM's and the Space Station.

3.2.1.7 RAM onboard systems shall be capable of on-orbit checkout controlled from the Station.

3.2.1.8 RAM's shall be pressurized and depressurized by the Space Station.

3.2.1.9 RAM thermal control systems shall be completely independent of the Space Station thermal control system.

3.2.2 Physical

3.2.2.1 RAM and MSS shall use a standard docking mechanism.

3.2.3 Reliability

This paragraph is not applicable to this appendix.

3.2.4 Maintainability

This paragraph is not applicable to this appendix.

3.2.5 Operational Availability

3.2.5.1 The 6-man ISS orbital configuration shall be operationally available to support an attached RAM by May 1980.

3.2.6 Safety

3.2.6.1 RAM's shall abide by station safety policies and procedures while docked to the station configuration.

3.2.7 Environment

This paragraph is not applicable to this appendix.

3.2.8 Transportability/Transportation

This paragraph is not applicable to this appendix.

3.3 Design and Construction Standards

This paragraph is not applicable to this appendix.

3.4 Logistics

This paragraph is not applicable to this appendix.

3.5 Personnel and Training

3.5.1 Station crew time above station-keeping and maintenance requirements shall be made available for the performance of RAM or integral experiments.

3.6 Exchange Hardware and Delivery Dates

None identified

3.7 Exchange Services and Performance Periods

None identified